

The Hard X-ray Imager onboard IXO

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ABSTRACT

The Hard X-ray Imager (HXI) is one of the instruments onboard International X-ray Observatory (IXO), to be launched into orbit in 2020s. It covers the energy band of 10–40 keV, providing imaging-spectroscopy with a field of view of 8×8 arcmin². The HXI is attached beneath the Wide Field Imager (WFI) covering 0.1–15 keV. Combined with the super-mirror coating on the mirror assembly, this configuration provides observation of X-ray source in wide energy band (0.1–40.0 keV) simultaneously, which is especially important for varying sources. The HXI sensor part consists of the semiconductor imaging spectrometer, using Si in the medium energy detector and CdTe in the high energy detector as its material, and an active shield covering its back to reduce background in orbit. The HXI technology is based on those of the Japanese-lead new generation X-ray observatory ASTRO-H, and partly from those developed for Simbol-X. Therefore, the technological development is in good progress. In the IXO mission, HXI will provide a major assets to identify the nature of the object by penetrating into thick absorbing materials and determined the inherent spectral shape in the energy band well above the structure around Fe-K lines and edges.

Keywords: International X-ray Observatory, Hard X-ray Imager, X-ray Astronomy

1. INTRODUCTION

Evolution of universe is illuminated with a variety of high-energy or hot ($\sim 10^6$ – 10^9 K) phenomena: birth and death of stars, collapse of stellar core and generation of compact objects like neutron stars and black holes, growth of super-massive black holes and its co-evolution with host galaxy, formation and evolution of groups and clusters of galaxies, and heavy element synthesis in super nova explosion. All these phenomena are best accessible via X-ray observation. With its advanced optics and one of the highest sensitivity among energy-bands ranging from radio to TeV gamma-rays, X-ray observatories after 1980's became a major, indispensable measure to understand the physics in the vast universe. International X-ray Observatory (IXO) is proposed to be launched into orbit around 2020's. With its unprecedented effective area of >3 m² at 1.5 keV realized by newly developed X-ray mirror assembly (Flight Mirror Assembly; FMA), IXO is a real break through enabling us to dig into the early universe, where rapid growing of super-massive black holes and formation of the largest self-bound system in the universe, clusters and groups, are taking place. It also enables us to observe nearby objects with high statistics, opening a window to truly resolve the time-profile of materials falling into compact objects.

IXO is equipped with a total of five instruments sharing the same optics, including the X-ray Microcalorimeter Spectrometer (XMS)¹ with an energy resolution of 2.5 eV, and the Wide Field Imager (WFI)² working in 0.1–15 keV band with 18×18 arcmin² wide field of view (FOV) to explore the high-energy universe. The five instruments will be located at the mirror foci by turn, providing the best means to observe the object in query.

The Hard X-ray Imager (HXI), combined with the super-mirror coating option to the mirror is defined as an attachment to the WFI system. The HXI is designed to extend the band-path of WFI to as high as 40 keV and

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mounted in tandem to the WFI. This configuration originates from ASTRO-H (ex.NeXT) concept,³ of which the basic concept comes from earlier paper.⁴ Because of significant vignetting effect of the X-ray mirror in the hard X-ray band, the FOV required to the HXI (8×8 arcmin²) is a bit smaller compared to those required to the WFI 18×18 arcmin². The HXI technology is based on those of the Japanese-lead new generation X-ray observatory ASTRO-H,⁵ and partly from those developed for Simbol-X. Therefore, the technological development is in good progress. Technical details will be presented in the following sections. To achieve good ($\Delta E \sim 1$ keV full width at half maximum: FWHM) energy resolution for spectroscopy, which is also useful to mask-out line emissions in the detector background spectra, semiconductor technology is utilized. This approach also enables us to achieve good (a few 100 μ m) positional resolution. Sophisticated active shielding technique is also applied to reduce the detector background induced by cosmic-ray particles and high energy photons coming other than the target sources.

IXO is currently in the phase of defining the instrument basic design; defining mass, physical envelopes, power, temperature requirements and science outputs. In this paper, we will summarize the current design of IXO/HXI. Science requirements, which defines the detector design are summarized in the next section. Basic detector concepts are presented in section 3, followed by the status of seed technologies shown in section 4. Brief summary is presented at the last section.

2. HXI SCIENCE DRIVERS AND REQUIREMENTS

The HXI system provides significant increase of science outputs, which is strongly supported by the science board of the IXO. It is also designed to be small in its size, weight and cost, fully utilizing the new and well developed technologies. The major field in IXO science requiring hard X-ray coverage is the sciences on strong gravity. For example, HXI system enables us to observe one of the hottest objects, rapidly growing super-massive black holes.⁶ In current models, these black holes is considered to be located in a thick curtain of materials, to be processed by the black hole in near future, fueling the great eater to rapidly increase its weight, as well as providing strong out-flows, or winds, which is considered to affect the host galaxy environment significantly.⁷ With its high penetration power, hard X-rays can identify this activity in the phase hidden in the dust.

Resolving the trajectory of matters falling into black holes is another key item regarding this issue. From existing observational results, fluorescence Fe-K line emission around ~ 6 keV are believed to provide direct measure of the orientation of accretion disk surrounding the black hole.^{8,9,10} The line emission, however, is so widely broadened that we need to understand the shape, and hence the origin, of the underlying “apparently power-law shaped” emission. Because of the broadened line and edge feature around 4–10 keV, we need good spectral information at both below 4 keV and above 10 keV. Recent analysis of the X-ray spectra of super massive black holes shows that this modeling is the key to finally obtain a robust understanding of Fe-K line feature.

Since the HXI combined with the WFI provides a general purpose imaging spectrometer working on the wide 0.1–40 keV band, it can provide valid information to almost all fields of X-ray observations. For example, HXI certainly can obtain the temperature map with ever highest accuracy in the hottest ($kT > 10$ keV), most active clusters of galaxies with clear merging evidence, such as the Coma cluster and the “Bullet cluster”.¹¹ Cavities in cluster center, generated by interaction of black hole out flow or jet with intra-cluster plasma, is also a good candidate.⁷ Super nova remnants are also a good object, so that the wide-band spectra can provide its synchrotron continuum shape, radiative recombination profile, and search for hard point source as a indication of collapsed core.

Detector specification required from science is summarized in table 1. In short, the HXI is required to provide hard X-ray imaging spectroscopy extension to the WFI, within the FOV of 8×8 arcmin, up to as high as 40 keV. Following this requirements, we designed the HXI with the best technology available. Our goal is to achieve these requirements with sophisticated, minimal and simple design.

3. DETECTOR CONCEPTS

3.1 Overview of the HXI detector

The HXI are aligned with WFI in tandem orientation at the foci of the mirror (flight mirror assembly ; FMA) with a focal length of 20 m. “Soft” X-rays below ~ 10 keV is absorbed in the WFI and “hard” X-rays with higher

Table 1. Scientific requirements to the HXI

Items	Values	Comments
Mirror effective area	150 cm ² @ 30 keV (goal: 350 cm ²)	Including detector efficiency
Spectral resolution	$\Delta E = 1$ keV (10–40 keV) FWHM	Also used to resolve-out the activation lines in background
Angular resolution	30 arcsec HPD (goal: 5 arcsec HPD)	Detector must over-sample the PSF image
Field of view	8 × 8 arcmin ²	The mirror shows rapid vignetting above the energy ~ 20 keV
Absolute timing	100 μ s	Higher timing resolution is used within the HXI for anti-coincidence

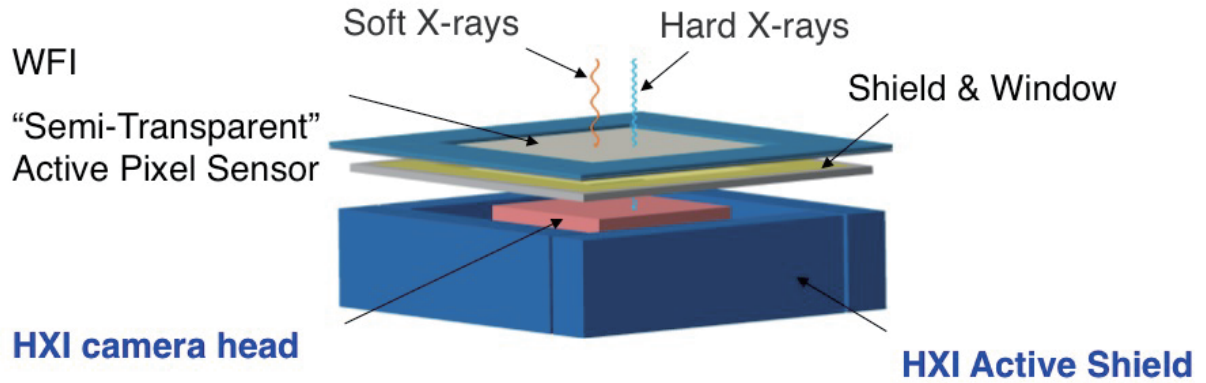


Figure 1. Design concept of HXI in combination with WFI. Two detectors are aligned in tandem orientation at the foci of the mirror. "Soft" X-rays below ~ 10 keV is absorbed in the WFI device. "Hard" X-rays with higher energy penetrates it and then detected by the HXI. Bottom hemisphere of HXI imager part is surrounded by an active shield to reduce background significant above ~ 10 keV.

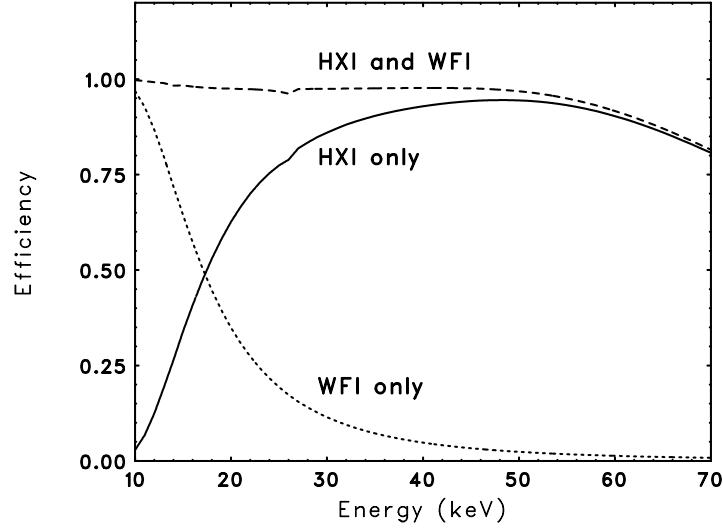


Figure 2. Detector efficiency of the HXI. Two layers of 0.5 mm thick Si devices and a 0.75 mm thick CdTe device is considered. The WFI-APC is calculated as a 0.45 mm thick Si device. Efficiency with HXI only (solid), WFI only (dotted) and combined (dashed) are shown.

energy are detected by the HXI. Bottom hemisphere of HXI imager part is surrounded by an active shield to reduce non X-ray detector background significant above ~ 10 keV. See Figure 1 for the tandem concept design. The HXI itself consists of 2-layers of 0.5 mm thick double-sided Si strip detector (DSSD)¹² as medium energy detector and a 0.75 mm thick double-sided strip CdTe detector (DS-CdTe)¹³ as high energy detector. The latter device has an option to be designed as CdTe pixel detector.¹⁴

One of the rolls of the DSSD layers is to provide energy-band extension to as high as 20-30 keV with low background. Although photo-absorption probability of Si is limited, as a material it does not show significant activation even hit by numbers of high-energy protons in orbit. CdTe activation is expected to generate some numbers of radio isotopes generating detector background. Since CdTe is not needed below 20-30 keV, we can realize low background, high sensitivity observation utilizing DSSDs. Another roll of the DSSD layers is to shield the WFI detector from possible low energy (< 10 keV) photons generated in CdTe and shield materials of the HXI. The HXI system utilizes active shielding concept with a typical coincidence window width of a few μ s. Thus any prompt emission from high-energy cosmic-rays penetrating the detector and its surrounding can be easily discarded. On the other hand, WFI is not designed to provide such high timing resolution, because of its large FOV, and its background reduction is based on passive shielding design. DSSD layers with more than double the thickness of WFI detection part will provide an efficient background filter, working in passive mode for WFI and active mode for HXI.

In Figure 2, efficiency curve of each detector and those combined are shown. The HXI becomes the major detector above ~ 17 keV. The required energy band of HXI is up to 40 keV and the efficiency is high enough up to this energy. We are designing the detector to cover up to ~ 80 keV. This is in principle for detector calibration, i.e. we can utilize ^{241}Am source with its 14–59.5 keV lines at on-ground and in-orbit calibrations. The ^{241}Am source will be mounted on the filter wheel of the WFI/HXI, at the calibration isotope position. The higher energy band spectra is also important for detector background estimation, which will become much important especially in diffuse source analysis.

The foci of the mirror is positioned on the WFI device, because angular resolution is much important in soft X-ray bands with thousands of objects in the FOV. The HXI imager, the 2 DSSDs and a CdTe devices, are required to be located within 30 mm from the foci so that defocusing is minimized. The hard X-ray super mirror coating is currently planned to be implemented within a diameter of 75 cm of the mirror. The 30 mm set-back causes ~ 10 arcsec degradation in HPD of the PSF image of the mirror. The angular resolution goal of 5 arcsec

HPD is therefore out of the scope with current design and the HXI's design goal is set at covering positional resolution as high as ~ 10 arcsec.

3.2 System Design

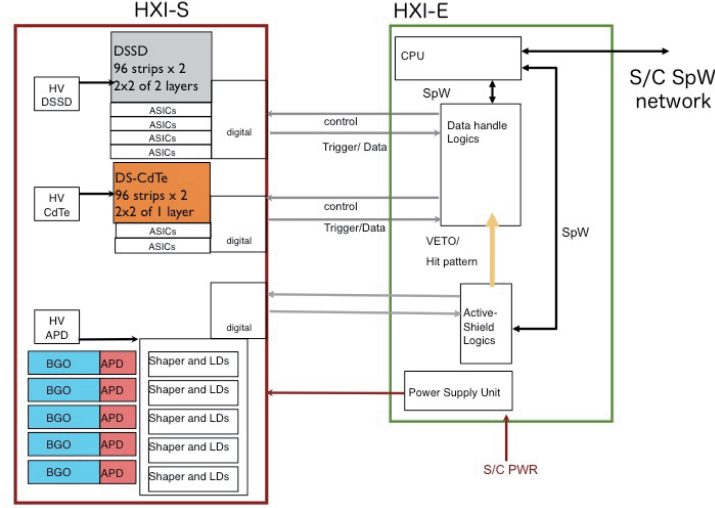


Figure 3. System block diagram of the HXI, made of the sensor part (HXI-S) and the electronics part (HXI-E). The DS-CdTe imager module can be replaced by CdTe pixel imager as an option. Active shield system made of 2 cm thick BGO read out via APD can also be replaced by passive Lead/Tungsten shield with plastic scintillator read out via MAPMT. See text for detail.

The HXI system consists of 2 boxes, the sensor part (HXI-S) and the electronics part (HXI-E). HXI-S consists of the DSSD module, the CdTe imager module, and the active shield module. HXI-E composes of logic boards equipped with Field Programmable Gate Arrays (FPGAs) which converts all sensor signal to a serial signal standard, SpaceWire*. It also provides regulated power lines used in HXI-S. HXI-E is also equipped with a CPU board with SpaceWire interfaces to both front-end and satellite back-end. This system configuration is designed following the Hard X-ray Imager instrument onboard ASTRO-H.¹⁵

The front-end part of HXI-S has a few options. To proceed the project, we designed the system default based on ASTRO-H heritage, since this case will have the highest technical readiness level (TRL) after its launch planned in 2014. However, rapidly developing technologies especially in the front-end ASICs (Application Specific Integrated Circuits) and the CdTe devices together with difference of orbit between ASTRO-H and IXO made us consider alternative technologies as an option. By carefully designing the system, we come to a HXI-S design with modular concept, i.e., each major modules can be replaced with its option technology with little impact on overall detector design. The design work benefits from the fact that the original ASTRO-H HXI is of highly modular design with clear interface between each major components.

The base-line DSSD module composes of 2-layers of 0.5 mm thick $48 \times 48 \text{ mm}^2$ wide DSSDs read out via analog ASICs. There is currently no option in this module. The CdTe imager module has two options, a double-sided CdTe strip detector with a configuration the same to the DSSD and an array of CdTe pixel detectors. The read-out analog ASIC for Si and CdTe devices is also made up of two options, the base-line IDeF-X family¹⁶ from CEA/Saclay developed for Simbol-X and the optional VATA family¹⁷ from Ideas ASA. used in ASTRO-H. In both cases, the front-end electronics card or ASIC itself is equipped with ADCs and all signals are digitalized at the very early phase, to minimize electrical noise. Technical detail is shown in preceding section.

In view of optimizing the weight and background level, the active shield module also is made up of two options, a 2 cm thick BGO crystal read out via APD (avalanche photo diode)¹⁸ and passive Lead/Tungsten

*see <http://spacewire.esa.int/content/Home/HomeIntro.php>.

shield with plastic scintillator read out via MAPMT (multi-anode photo-multiplier tube). Former is of ASTRO-H origin and the latter is of Simbol-X. Intensive background estimation study is required to determine which option is the better case in this design.

Design specifications are summarized in Table 2. Both cases of base-line strip design and optional CdTe pixel design are shown. With the focal length of 20 m, 250 μm and 600 μm positional resolution correspond to 2.6 arcsec and 6.2 arcsec, respectively. In both cases, the detector position resolution is high enough to over-sample the required 30 arcsec HPD PSF image, while in the 10 arcsec HPD case (a 5 arcsec mirror with defocusing by set-back of <30 mm) the latter value is a bit large.

Table 2. Specifications of HXI

Characteristics	Base-line strip design	Option 2-dim CdTe pixel
Detector Type	Si and CdTe Schottky Diode double sided strip	Double-sided Si strip and CdTe pixel devices
Strip pitch	250 μm (both side)	250 μm (both side, for Si layer)
Pixel Pitch	NA	< 600 μm (for CdTe pixel)
Number of readout channels	2-side read-out, in total 768 strips per layer (1 CdTe, and 2 layers of DSSD) in total 2304 strips	768 strips per DSSD layer (1536 strips in total for DSSD) and 6k up to 31k channels for 50 mm wide CdTe pixel detector
Array Size (mm^2)	48×48	Same
Field of View (arcmin^2)	8×8	Same
Energy range	10–80 keV (40–80 keV is for in-orbit calibration with ^{241}Am source)	Same
Energy Resolution	$\Delta E < 1 \text{ keV}$ (FWHM)	Same or better
Detector Background	$\sim 5 \times 10^{-4} \text{ cts keV}^{-1} \text{cm}^{-2} \text{s}^{-1}$	Same
Count rate/source with 10% pile-up	20k cts s^{-1} (Note: Crab is expected to generate < 500 Hz only)	Same or better
Timing accuracy	< 10 μs relative (100 μs absolute)	Same
Typical/Max telemetry	11 kbs^{-1} (256 kbs^{-1} max. for ground calibration)	Same
Operating Temperature	Semiconductor Detectors $-40 \pm 2^\circ\text{C}$ (option with -30°C) BGO active Shiled $-15 \pm 2^\circ\text{C}$ Electronics $20 \pm 20^\circ\text{C}$	Same
Instrument Power, excluding thermal control	43 W + Heat-up heater	Same
Total Mass (no margin)	21.5 kg	Same

4. TECHNOLOGY STATUS

4.1 Imager

4.1.1 The base-line design

The imager base-line design is based on the HXI of the ASTRO-H mission. Since the launch date of ASTRO-H is planned to be at 2014, the development works are in good progress. The HXI base-line design employs an array of double-sided strip detectors read out by front-end ASICs bonded to strip electrodes, orthogonally implemented on both sides of the semiconductor wafer. To obtain good imaging quality, the detector is based on highly uniform CdTe semiconductor from ACRORAD, and the Si semiconductor from Hamamatsu (HPK) or other developers. In each of the DS-CdTe and DSSD layer, the current baseline design employs a 2×2 array of $2.4 \times 2.4 \text{ cm}^2$ -large devices to reduce development risk. Each detector has 96+96 strips with a strip pitch of

250 μm and strip length of 24 mm. These double-sided strip layers provide with an 8 arcmin square FOV and a fundamental pixel size of 2.6 arcsec with a 20 m focal length. Read out channel number is thus $(96+96) \times 4 = 768$ per layer, and 2304 in total of 3 layers.

Thickness of 0.5 mm or 0.75 mm is considered for DS-CdTe. Aluminum is used as the electrode in the anode-side and Platinum in the cathode-side. The signal from a photon absorbed in the detector is detected through the strip electrodes implemented in both sides of the layer, and fed directly into analogue chains implemented in the ASICs. One side of the read-out front-end electronics are biased as a whole with a voltage of about 600–1200 V to obtain sufficient charge collection efficiency in this device.

Inside each module, a derivative of IDeF-X ASIC are used in the base-line design. The ASIC is a low noise, radiation hard front-end electronics¹⁹ devoted to the readout of low leakage current and low capacitance semiconductor detectors. It includes 32 analog chains, each with a charge sensitive amplifier (CSA) connected to a shaping amplifier with a comparator and a peak-hold circuit. Currently ADC is mounted on dedicated independent ASIC, located to the very next of the front-end ASIC. An option ASIC, which is used in ASTRO-H/HXI, is a derivative of VATA family.¹⁷ Most of the test of double-sided strip imagers are based on this ASIC, at this moment. Combination of CSA connected into two sets of shaping amplifiers, one with a comparator and another with sample-and-hold circuit is used in the ASIC. Wilkinson-type ADC is also equipped in all channels. According to the measurements by prototype detectors and analog circuits similar to those proposed for IXO-HXI,¹³ an energy resolution of better than 1 keV (FWHM) can be achieved in the energy range from 10 keV to 80 keV when we operate the detector at 233 (or 243) K. Note that since analog ASIC technology is rapidly evolving, this approach, i.e. keeping the interface similar between two independent analog ASICs selected as a base-line and backup technology, is essential to reduce development risks.

In Figure 4, we present photo of one of the prototype DS-CdTe detector and a shadow image obtained with this device. A ^{241}Am source spectra is also shown in the right panel of Figure 6. A new DS-CdTe device for ASTRO-H, with 250 μm pitch strip in 128+128 channel configuration and detection area of $32 \times 32 \text{ mm}^2$ is also in development (See Kokubun et al. 2010, this proceedings¹⁵). The 2.5 cm-large DS-CdTe will be developed based on this technology.

DSSDs will also have a thickness of 0.5–0.6 mm. The read out system is the same to that of the CdTe strip detectors. Bias voltage for the DSSDs is about 250 V. In order to reduce the gap in the image, a new monolithic DSSD device with $48 \times 48 \text{ mm}^2$ detector area is also planned. Even in this case, the strip electrodes will be separated into 24 mm in length to reduce leakage current and capacitance of each strip electrodes to obtain higher energy resolution. We have already demonstrated DSSDs with a size of $25.6 \times 25.6 \text{ mm}^2$ in 64+64 strip configuration and $38.4 \times 38.4 \text{ mm}^2$ in 96+96 strip configuration, both with 400 μm strip width^{20, 21}. DSSDs with finer strip pitch (75 μm) is also working well.²² Photo of a 25.6 mm wide DSSD and a shadow image obtained with the 38.4 mm wide device are shown in Figure 5, together with the ^{241}Am source spectra in the left panel of Figure 6. In all these results, VATA ASICs with similar analog design are utilized.

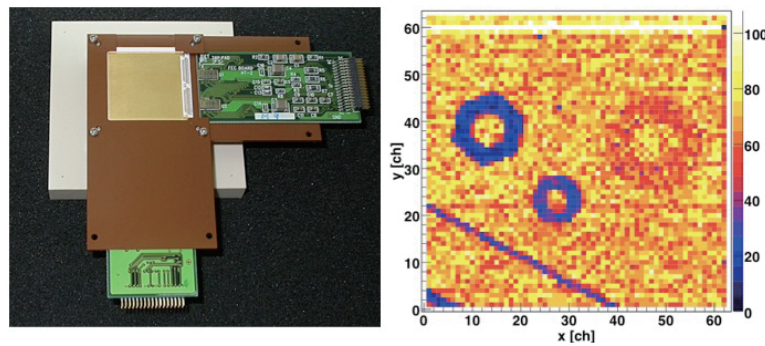


Figure 4. Prototype DS-CdTe with 400 μm pitch 64+64 strip with 25.6 mm wide area read out via VATA analog ASIC. Left panel shows the setup, and right panels shows the 80 keV shadow image obtained with the device. Figures from Watanabe et al. 2009¹³

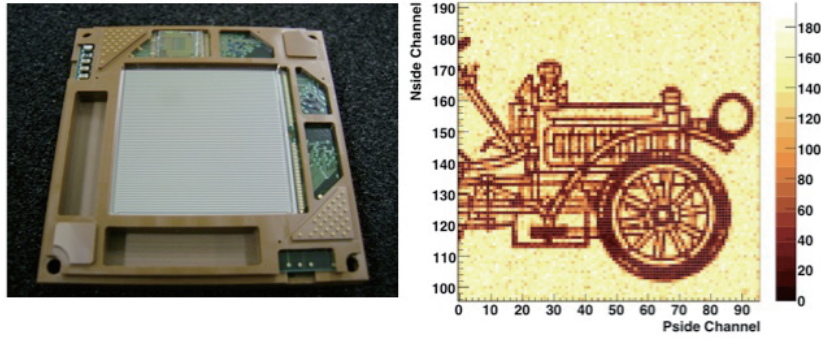


Figure 5. Left panels is the photo of rototype DSSD with $400\ \mu\text{m}$ pitch 64+64 strip with 25.6 mm wide area read out via VATA analog ASIC. Right panel is the $\sim 30\ \text{keV}$ shadow image obtained with the $38.4 \times 38.4\ \text{mm}^2$ DSSD. Figures from Takeda et al. 2007²¹

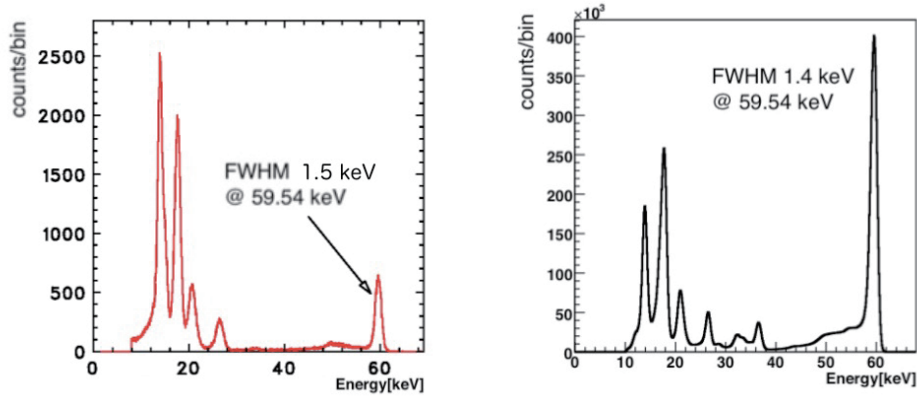


Figure 6. ^{241}Am spectra obtained with (left) the 4 cm DSSD and (right) the 1.3 cm DS-CdTe spectra obtained at -20°C . Figures are from Takeda et al. 2007²¹ and Watanabe et al. 2009.¹³

4.1.2 CdTe pixel option

Another technology option is to use the CdTe 2-dim pixel device in place of the DS-CdTe, with a pixel pitch of $< 600\ \mu\text{m}$ or $< 6.3\ \text{arcsec}$ resolution. This is the heritage technology originally proposed for Simbol-X.¹⁴ Because of smaller electrode area per channel, better energy resolution and higher through-put is expected in this case. As a matter of fact, the dark current in each channel as well as the input stray capacitance is drastically reduced with respect to a strip detector as DS-CdTe. Beside the high level of technological maturity of this option, the drawback of this approach in the current technology is that the pixel pitch gets a bit larger. Nevertheless, the pixel size of $< 600\ \mu\text{m}$ is applicable since current optics design are considered to provide PSF with $> 10\ \text{arcsec}$ HPD including the effect of the set-back of the CdTe imager. New technology with finer pixel pitch ($< 300\ \mu\text{m}$) is also under development and will reach a reasonable technological maturity within the IXO time scale.

The pixel detector option for HXI is currently based on modular assembly of two independent hard X-ray camera of $40 \times 20\ \text{mm}^2$. Each camera, namely MACSI (Modular Assembly of Caliste Spectro-imager) (figure 7-bottom left) is made of an array of 4×2 elementary detection units called Caliste 256. The latter is a hybrid module made of a stack of eight analogues front-end ASIC IDeF-X (figure 7 top left) installed perpendicularly to the detection surface. Each individual input is then connected to a pixel of CdTe array. All pixels are surrounded by a guard ring that helps to drive the non metal side dark current contribution out of the readout channels. The high voltage is applied from the top common electrode.

Thanks to optimization of both the CdTe detectors, ASIC and hybrid design, Caliste 256 is able to reach very good spectral performances. At room temperature, a spectral resolution of 760 eV and 950 eV FWHM are

achieved at 14 and 59.5 keV, respectively. The low threshold is as low as 2 keV. Cooling down the device of course helps the spectral response but also stabilize the CdTe detector with respect to the polarization effect. Caliste is designed to operate in the range from -40°C to $+20^{\circ}\text{C}$. CdTe pixel device is currently tested with IDeF-X ASIC family.

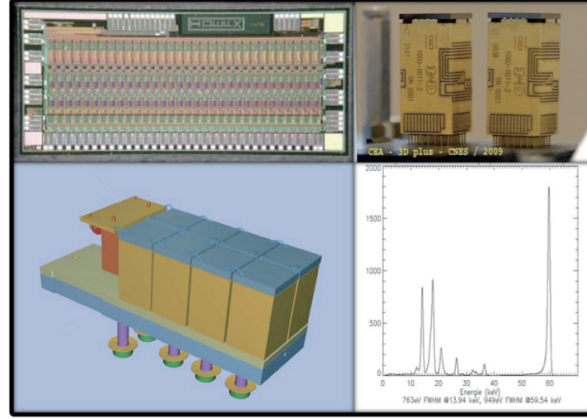


Figure 7. (*Top-left panel*): IDeF-X V2, 32 channels low noise and radiation hard front-end ASIC for CdTe pixel array readout. (*Top-right panel*) couple of Caliste 256 hybrid module - a 256 CdTe pixel array equipped with $580\ \mu\text{m}$ pitch pixels are installed on top of a electronic front-end made of a vertical stack of 8 IDeF-X V2 ASICs. Each ASIC reads two rows of pixels. (*Bottom-left panel*) CAD view of a MACSI camera - 4×2 Caliste 256 are installed on a PCB equipped for its own massive thermal drain. (*Bottom-right*) Spectral response of Caliste 256 - this spectrum is the sum of 256 calibrated spectra acquired simultaneously on a CdTe Schottky sample, 1 mm thick, $+20^{\circ}\text{C}$, 400 V.

4.2 Shield design

In order to obtain high sensitivity with the HXI, the DSSDs and DS-CdTe/pixel-CdTe detectors are actively shielded by BGO scintillators in the base-line design. This shield is indispensable, as the non X-ray background is the dominant source of the background in the energy range of the HXI. A thickness of $\sim 2\ \text{cm}$ for BGO will be required, not only for shielding against background photons but also for reducing the number of particles that reach the CdTe detector and give rise to activation. Scintillation photons from BGO are read by avalanche photo-diodes (APD)¹⁸ from Hamamatsu (HPK). The APDs require a bias voltage of $\sim 400\ \text{V}$. BGO with its holding structure, APD, analog chain and digital signal processing are similar to those used in ASTRO-H HXI in the baseline design. Prototype detector with a BGO and APD with similar size of the IXO-HXI design shows good lower threshold of $\sim 60\ \text{keV}$.²³

Another option for the shielding derived from the study made for the Simbol-X mission consists of a plastic scintillator module and by a passive shield placed all around it. The passive shielding allows stopping high energy photons (from Cosmic X-ray background: CXB) and their resulting fluorescence. The plastic scintillator aims at detecting protons passing through the HXI detectors. The visible-light/UV photons created in the plastic are captured by optical fibers and conducted into a multi-anodes photomultiplier (MAPMT) further away. The resulting MAPMT current is amplified and treated by the front end electronics, which compare it to an adjustable threshold and send a trigger each time the photomultiplier output is greater than this threshold. A representative breadboard of the anti-coincidence system, made with a BC400 plastic scintillator, Y11 optical fibers, and a R7600-M16 Hamamatsu 16 pixels multi-anodes photomultiplier is shown in figure 9. This breadboard has been successfully tested in the Tandem proton accelerator in Orsay, France, and resist to vibration tests representative of the Simbol-X mission.

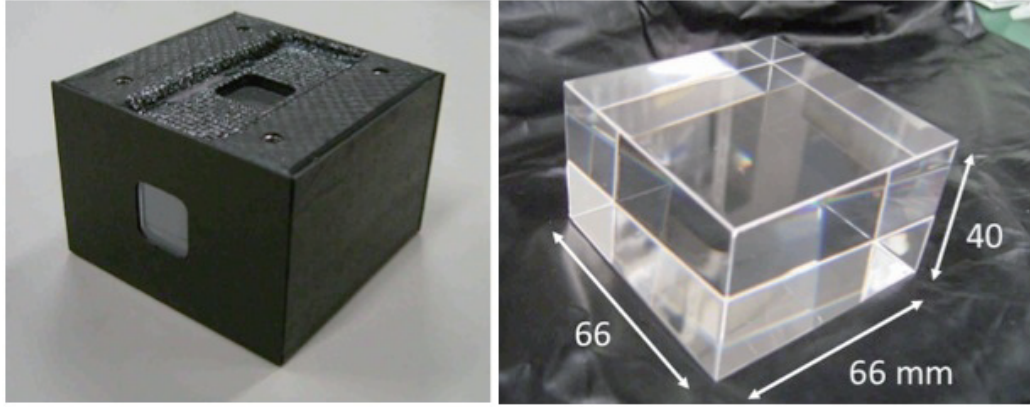


Figure 8. The BGO scintillator crystal used in ASTRO-H HXI as an active shield. (left) covered with reflector and CFRP support and (right) the naked crystal.

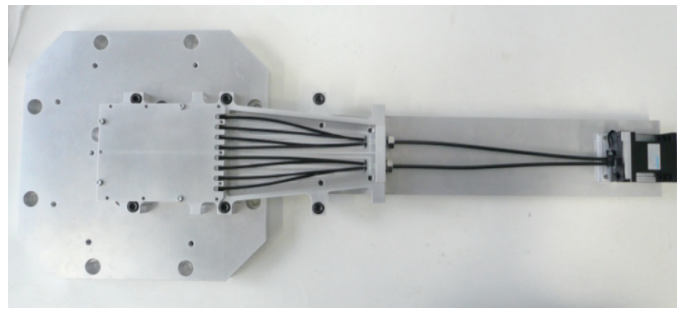


Figure 9. The plastic scintillator connected to a multi-anodes PMT demonstrated as an alternative active shielding against particles. This system is to be coupled with passive CXB photon shield.

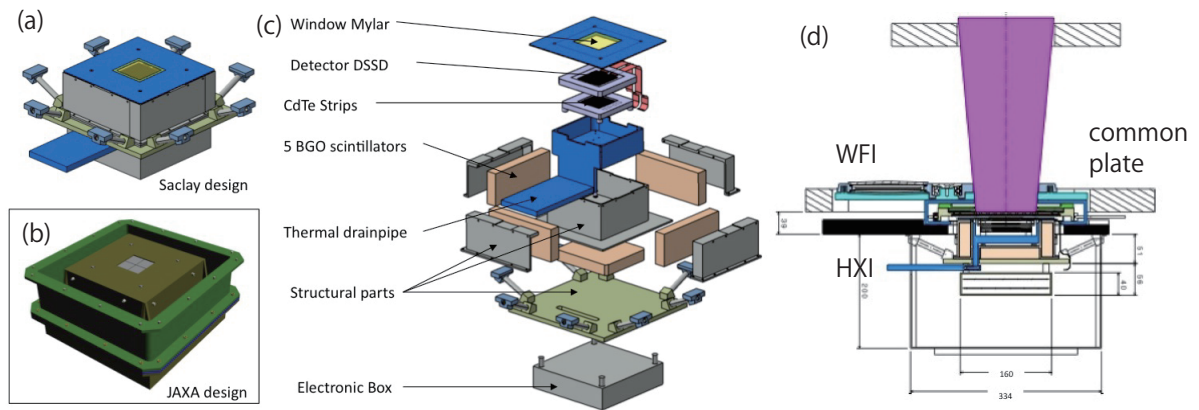


Figure 10. Mechanical drawings of HXI-S. Based on the same concept, two independent designs are in progress in (a) Saclay and (b) JAXA. (c) Parts drawings of French design. HXI-S is made of DSSD, CdTe and active shield modules, front-support electronics box, cold finger and structure interface to WFI. (d) HXI is located beneath the WFI mounted on the common plate and sharing the same foci. Field of view to the mirror optics is shown as a magenta region.

4.3 Mechanical and thermal design

Structure of the HXI-sensor part is designed to the following concept. Mechanically, the HXI-sensor part is integrated with that of the WFI. The two systems share the same foci, and designed to be mounted on common interface plate, which will then be mounted to the satellite's "Movable Instrument Platform". By this design, the WFI/HXI system will be handled as a single unit from the satellite system in the mechanical point of view. Because the HXI-imager part, the DSSDs and CdTe imagers, shall be mounted within 30 mm from the WFI imager, two devices are located very near and thermal design is not completely independent. The operation mode of the detectors is different and hence the operating temperature is $< -100^{\circ}\text{C}$ and $-40 \sim -30^{\circ}\text{C}$ in the WFI and HXI devices, respectively. In addition, the common interface plate will be at "room temperature" in the satellite. Therefore, we are designing the HXI detector to be as independent as possible from the WFI and satellite in thermal point of view. From electrical point of view, two systems are completely independent, i.e. there is no electrical line directly connecting these two instruments.

Internal mechanical structure of the HXI sensor is made of 4 major components: imager part with thermal drainpipe, shield part which construct major component in its weight, front-support electronics box to enable locating the main electronics box ~ 2 m away from the sensor part, and mechanical interface to the common plate which is also designed to thermally isolate the HXI sensor from the plate. Most of the surface of the HXI sensor part will also be covered with multi layer insulater (MLI) to reduce radiative thermal coupling to the satellite system. Figure 10 shows one of the concept designs of the HXI sensor part. In panel (d), cut-out diagram after integration with WFI is also shown. An entrance window made of Aluminized mylar will be located on top of the imager, to be used as a dust-cut window when independently operated as the HXI system on ground calibration, and also for thermal decoupling to the WFI imager device. To reduce molecular contamination from HXI to much cooler WFI imager, the window and its support structure design is still evolving.

5. SUMMARY AND CONCLUSION

Hard X-ray Imager onboard IXO provides an hard X-ray energy coverage with imaging X-ray spectroscopy with a field of view of 8 arcmin. Combined with the Wide Field Imager, it provides a wide band-pass from 0.1 to 40 keV, which enables us to identify highly obscured objects, resolve out the spectral components of the X-ray emission from super massive black holes, and detect any hard components in clusters of galaxies. HXI utilizes double-sided strip detectors made of Si and CdTe as its main imager device, and BGO scintillator coupled to APD as an active shield as a baseline. All these technologies are based on ASTRO-H and Simbol-X heritage. System design is proceeding, and we have a feasible detector design. Technical development of HXI will proceed rapidly, partly by ASTRO-H project proceeding, and partly by independent development activity in both France and Japan.

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